Thayer, D. W., J. B. Fox, Jr., and G. Boyd. 1992. Effects of gamma radiation at normal processing temperatures on the B vitamins of pork chops and chicken breasts and on the survival of salmonellae. p. 63-70. *IN* Harmonization of regulations on food irradiation in the Americas, Proc. Inter-American Meeting, Orlando, FL. 27 Nov. - 1 Dec, 1989. IAEA-Tecdoc-642. International Consultive Group on Food Irradiation, FAO, IAEA, WHO. International Atomic Energy Agency, Vienna, Austria.

EFFECTS OF GAMMA RADIATION AT NORMAL PROCESSING TEMPERATURES ON THE B VITAMINS OF PORK CHOPS AND CHICKEN BREASTS AND ON THE SURVIVAL OF SALMONELLAE

Abstract

The effects of 0 to 6.65 kGy of gamma radiation on the percentage of thiamin, riboflavin, niacin, pyridoxine, and cobalamin in pork chops and chicken breasts at -20° to +20°C were determined. Pork chops irradiated at 0°C and then cooked lost 5.6 and 17.6% thiamin at 0.3 and 1.0 kGy, respectively. The approved gamma radiation dose range for trichina control in the United States of America is 0.3 to 1.0 kGy. Much greater thiamin losses occurred in pork at radiation doses exceeding 3 kGy. The loss of thiamin was temperature dependent. Other vitamin losses were small or non-existent in both pork and chicken. Cooked chicken irradiated at 0°C lost 9.05% thiamin at 3.34 kGy and 25.8% at 6.65 kGy. Treating chicken meat with gamma radiation greatly increased the sensitivity of surviving cells of Salmonella typhimurium to the effects of cooking. An irradiation temperature between -20°C to +20°C significantly affected the survival of salmonellae in mechanically deboned chicken meat.

1. INTRODUCTION

The use of gamma radiation treatment at an absorbed dose between 0.30 and 1.0 kGy to control Trichinella spiralis in pork carcasses and fresh non-heat-processed cuts of pork carcasses was approved by the U.S. Food and Drug Administration in 1985 and by the U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS) in 1986 [1-2]. In 1987 FSIS filed a food additive petition with the U.S. Food and Drug Administration, "proposing that the food additive regulations be amended to provide for the safe use of sources of ionizing-radiation for reduction of food-borne pathogens in poultry products" [3]. In 1986 FSIS requested that the Agricultural Research Service study the effects of low- and medium-dose ionizing radiation at refrigerator temperatures on the vitamins of pork and poultry. The effects of sterilizing doses of ionizing radiation on the vitamins of meats generally at temperatures below -30°C had been studied but little information existed on low- to medium-dose effects on vitamins in meats at refrigeration temperatures [4-8]. The most relevant reference was that of Wilson [9] in which minced beef was irradiated at room temperature with X-rays at doses up to 3 kGy; in that study Wilson reported a loss of thiamin equivalent to 19.1% in air or 11.2% in nitrogen after a dose of 1 kGy. Both Thomas [8] and Wilson [9] reported smaller losses when the meat was frozen at the time of irradiation. The following report summarizes the

results of studies of the stability of vitamins and the survival of salmonellae in meats that were irradiated at refrigeration temperatures.

2. RADIATION EFFECTS ON PORK CHOP AND CHICKEN BREAST VITAMINS

2.1 Methods

Details of the methods and results of this study were reported by Fox et al. in 1989 [10]. A central composite response surface design was used for the study as illustrated in Table 1. Each replicate sample consisted of seven center cut 2 cm-thick pork chops or five chicken breasts. There were six replicates for each dose and temperature except at 0°C at 0 and 3.5 kGy doses. The samples were gamma (Cs-137) irradiated in oxygen- permeable packaging at 0.12 kGy per min. One-half of the irradiated replicate samples were cooked to an internal temperature of 76°C.

TABLE I. STATISTICAL DESIGN AND IRRADIATION TREATMENT PARAMETERS FOR PORK CHOPS AND CHICKEN BREASTS

Irradiation Temperature °C	Number of Replicate* Samples					
	0	0.50**	1.75	3.50	5.25	7.00 kGy
-20		6		6		
-10			6		6	
0	10	6		10		6
10			6		6	
20		6		6		

Adapted from Fox et al., [10].

* Each replicate sample contained seven pork chops or five chicken breasts.

** Chicken was not irradiated at 0.50 kGy.

2.2 Results, pork chops

Of the five vitamins examined, thiamin was the most significantly affected. The response surface showing the predicted effects on the thiamin content of pork chops irradiated at the various temperatures and then cooked is presented in Fig. 1. The equation for the response surface is μg thiamin = 12.17 2.30xKGY - 0.000279xTEMP - 0.0283xKGYxTEMP + 0.1659xKGY^2 + 0.000222x$TEMP^2$. As is evident from the response surface, there are significant effects due to both radiation dose and temperature. The R-square value for the response surface equation is 0.92 indicating good agreement between predicted and experimental values. More detail can be obtained by examining

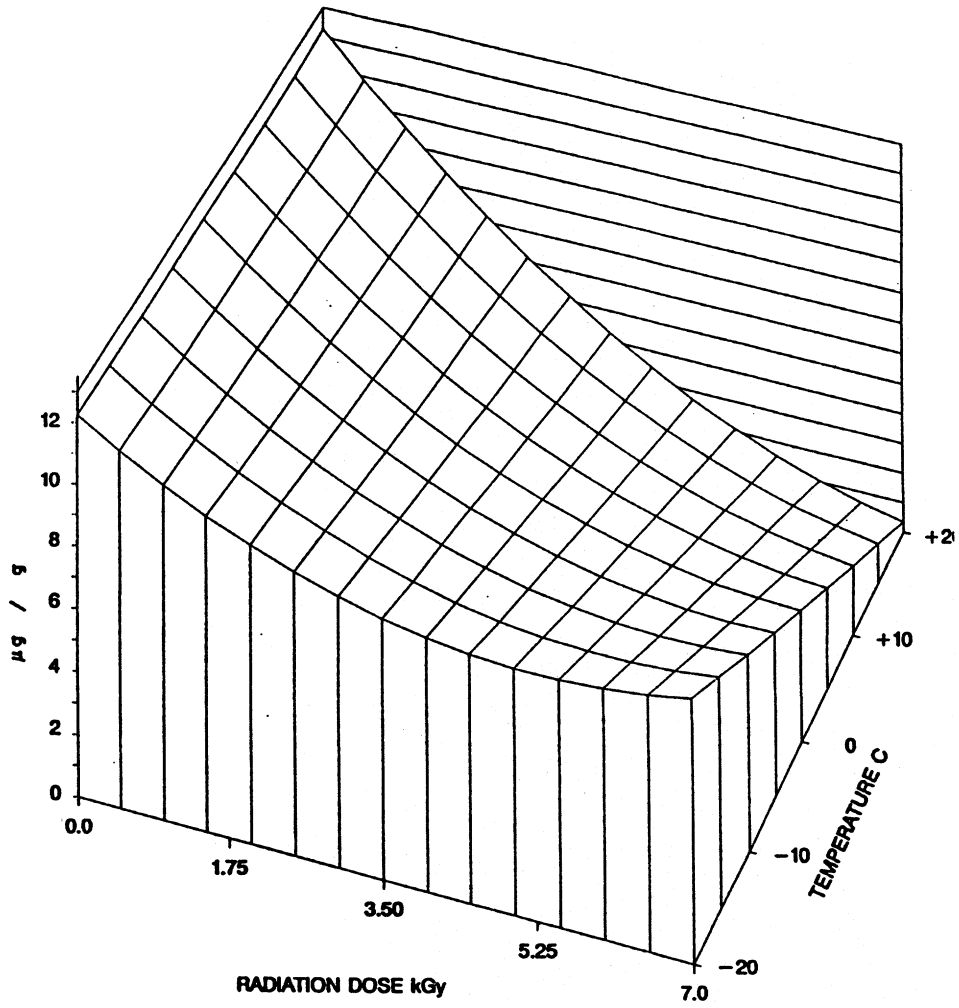

Fig. 1. Predicted thiamin content of cooked irradiated pork chops at various irradiation temperatures and absorbed gamma radiation doses. The concentrations are presented in micrograms thiamin per g of meat. Adapted from Fox et al., [10].

the predicted values in Table II for the effects of irradiation at 0°C. The loss of thiamin from pork chops after irradiating to a dose of 1.0 kGy and cooking is predicted to be 17.6%. The loss of thiamin, however, is far more significant at doses of 3.0 kGy or greater. Much smaller, though statistically significant, dose-related effects were observed on riboflavin and niacin in irradiated and cooked pork chops (Table II): a 4.4% loss of riboflavin and a 10.4% loss of niacin at a radiation dose of 1.0 kGy. Significant radiation effects were not observed on either pyridoxine or cobalamin in pork chops. Fox et al., [10] estimated that the net loss of thiamin from the American diet would be 1.5% if all pork were to be irradiated to the maximum permitted dose of 1.0 kGy.

TABLE II. PREDICTED VITAMIN LEVELS IN COOKED PORK CHOPS AND CHICKEN BREASTS IRRADIATED AT 0°C

kGy	THIAMIN µg/g		RIBOFLAVIN µg/g	NIACIN µg/g	
	Pork	Chicken	Pork	Pork	Chicken
0	12.17	0.70	2.72	113.9	110.3
0.5	11.06 (9.12%)	0.70	2.66 (2.2%)	107.5 (5.6%)	112.4
1.0	10.03 (17.6%)	0.69 (1.4%)	2.60 (4.4%)	102.1 (10.4%)	114.2
1.5	9.09 (25.3%)	0.68 (2.9%)	2.56 (5.9%)	97.8 (14.1%)	115.6
3.0	6.76 (44.4%)	0.64 (8.6%)	2.46 (9.6%)	90.8 (20.3%)	117.8
5.0	4.82 (60.4%)	0.55 (21.4%)	2.44 (10.3%)	95.6 (16.1%)	115.8
7.0	4.20 (65.5%)	0.42 (40.0%)	2.55 (6.2%)	116.8 (+ 2.5%)	111.2

Adapted from Fox et al., [10]
Values listed within ( ) are percentage loss or gain if preceeded by a +.

2.3 Results, chicken breasts

The effects of different irradiation temperatures and doses on the thiamin in the chicken breast meat, though statistically significant, were minimal. In Fig. 2 the response surface for the predicted thiamin values for irradiated and cooked chicken breast meat is essentially flat. The same scale was used for this figure as for pork chop thiamin in Fig. 1. The equation for the response surface is µg thiamin = $0.702 - 0.0039 \times KGY + 0.000282 \times TEMP - 0.000262 \times KGY \times TEMP - 0.00527 \times KGY^2 - 0.000079 \times TEMP^2$. Though the effects of the gamma radiation dose are less, they are present, as may be seen in Table II. The thiamin loss was 8.6% at 3.0 kGy, the maximum dose for which FSIS has requested approval. Though significant shifts were observed in the amount of niacin in chicken breasts subjected to different radiation doses, they were all apparent increases. One can only speculate that the irradiation treatment may have made the niacin slightly more extractable. This effect was much more apparent in the raw products for both niacin and riboflavin. There was no significant change in the percentage of riboflavin in irradiated cooked chicken breast meat.

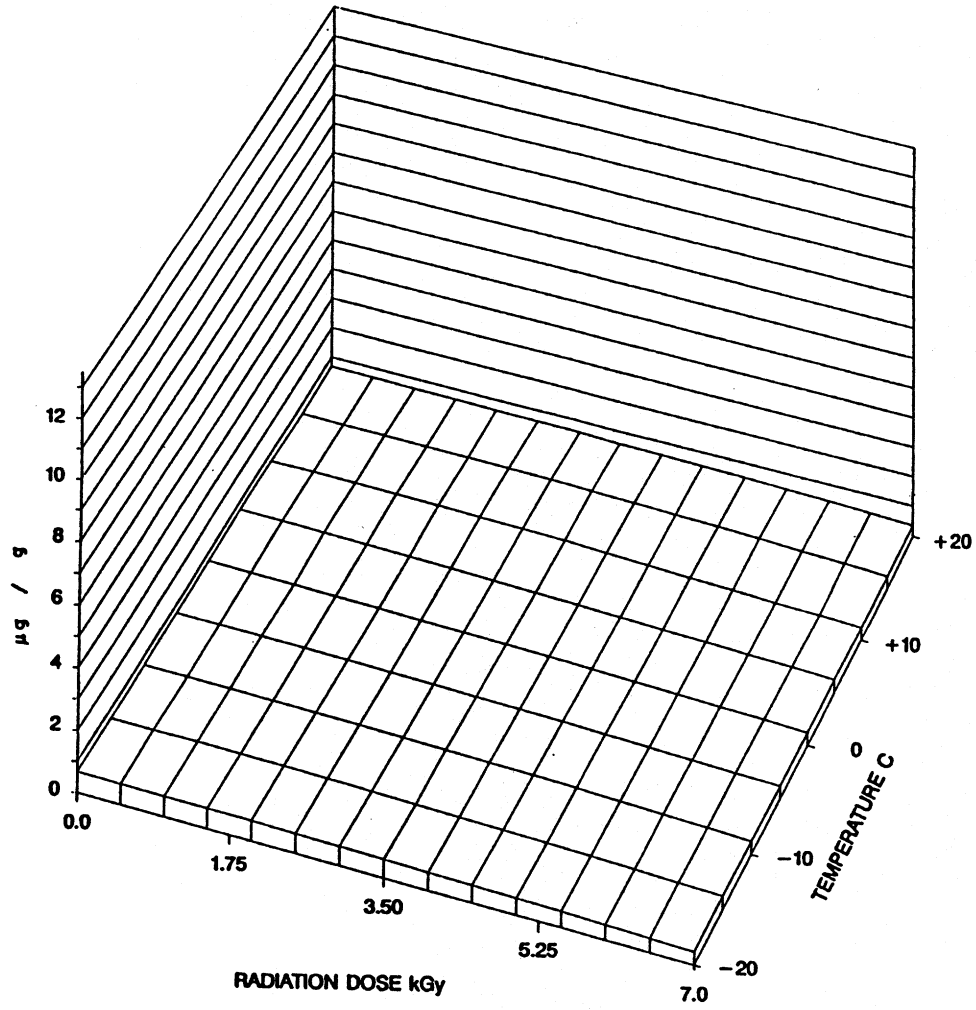

Fig. 2. Predicted thiamin levels in cooked chicken breast meat at various irradiation temperature and absorbed gamma radiation doses. The concentrations are presented in micrograms thiamin per g of meat. Adapted from Fox et al., [10].

3. RADIATION RESISTANCE OF SALMONELLA

3.1 Methods

Details of the methods and results were reported by Thayer et al., in 1989 [11]. Salmonella anatum ATCC 9270, S. arizonae ATCC 29933, S. dublin ATCC 15480, S. enteritidis ATCC 9186, S. newport ATCC 6962, and S. typhimurium ATCC 14028 were used for these studies with mechanically deboned chicken as the suspending medium. The mechanically deboned chicken meat, consisting of approximately 90% rib and 10% back meat, contained 63.1% moisture, 25.7% fat, and 11.4% protein. It was sterilized at -50°C, in vacuo, by gamma irradiation to an absorbed dose of 42 kGy. This was done to eliminate competition factors and to allow for accurate estimates of the surviving colony forming units by standard pour plate counts with a non-selective culture medium. The mechanically deboned chicken meat provided a very uniform and stable substrate for the studies. Thayer et al., [12] demonstrated that sterilizing chicken meat under these conditions produced no significant changes in its properties. Each sample of meat was inoculated with approximately 10^9 cells per gram of the appropriate organism. Nine radiation dose levels at 2°C were

serotypes and the very sharp differences in resistance to radiation over the range of -20°C to +20°C are evident. The presence or absence of air also may influence the results [11].

The results reported here indicate that the minimum radiation dose of 1.5 kGy proposed by FSIS would produce roughly a 2.8-decimal reduction of S. enteritidis when irradiated in mechanically deboned chicken meat at a temperature of 2°C, which should provide adequate protection from salmonellae. Even when all salmonellae are not eliminated by the irradiation treatment sublethal radiation injury may make them more sensitive to other types of processing or cooking effects. Preliminary results have indicated that irradiated salmonellae in mechanically deboned meat are also more sensitive to heat when the meat is cooked than are non-irradiated salmonellae.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the review and editorial advice of Dr. S. Palumbo, Dr. D. Derr, and Mrs. S. C. Thayer.

REFERENCES

[1] FDA (Food and Drug Administration), 21 CFR Part 179 Irradiation in the processing, and handling of food. Federal Register. 50 140 (1985) 29658-9.

[2] FSIS (Food Safety and Inspection Service), 9 CFR Part 318 Irradiation of pork for control of Trichinella spiralis. Federal Register. 51 10 (1986) 1769-71.

[3] FSIS (Food Safety and Inspection Service), [Docket No. 86F-0509] U.S. Department of Agriculture, Food Safety and Inspection Service; Filling of Food Additive Petition. Federal Register. 52 34 (1987) 5343.

[4] ALEXANDER, H. D., DAY, E. J., SAUBERLICH, H. E., SALMON, W. D. Radiation effects on water soluble vitamins in raw beef. Feder. Proc. 15 (1956) 921-923.

[5] JOSEPHSON, F. S., THOMAS, M. H., CALHOUN, W. K. Nutritional aspects of food irradiation: an overview. J. Food Processing Preservation. 2 (1978) 299-313.

[6] KENNEDY, T. S., LEY, F. J. Studies on the combined effect of gamma radiation and cooking on the nutritional value of fish. J. Sci. Food Agric. 22 (1971) 146-148.

[7] THOMAS, M. H., CALLOWAY, D. H. Nutritive values of irradiated turkey. II. Vitamin losses after irradiation and cooking. J. Am. Dietetic Assoc. 33 (1957) 1030-33.

[8] THOMAS, M. H., ATWOOD, B. M., WIERBICKI, E., TAUB, I. A. Effect of radiation and conventional processing on the thiamin content of pork. J. Food Sci. 46 (1981) 824-28.

[9] WILSON, G. M. The treatment of meats with ionising radiations. II. -Observations on the destruction of thiamine. J. Sci. Food Agric. 10 (1959) 295-300.

[10] FOX, J. B. Jr., et al. Effect of gamma irradiation on the B vitamins of pork chops and chicken breasts. Int. J. Radiat. Biol. 55 4 (1989) 689-703.

[11] Thayer, D. W., et al. Radiation resistance of Salmonella. J. Indus. Microbiol. 4 (1989) In Press.

[12] Thayer, D. W., et al. Toxicology studies of irradiation sterilized chicken. J. Food Protection. 50 (1987) 278-288.